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# Head and Trunk Movement Responses in Healthy Children to Induced Versus Self-Induced Lateral Tilt

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# Head and Trunk Movement Responses in Healthy Children to Induced Versus Self-Induced Lateral Tilt

DONNALEE MILETTE  
and ROSE MARIE RINE

The purpose of our study was to determine head and trunk movement responses that occur in healthy 7-year-old children during induced and self-induced lateral tilt. Twenty subjects, while tailor sitting on a tiltboard, participated in three trials of both induced and self-induced left and right lateral displacements. Measurements of neck and trunk lateral flexion; trunk counterrotation; and neck, trunk, and body anterior-posterior movement were obtained from slide transparencies made at three stages of tilt (original position, initial tilt, and full tilt). For each subject in the two test conditions, changes in these measurements between the stages of tilt were determined and compared. Based on the results of multivariate analysis of variance procedures, we concluded that 1) a significant difference in trunk counterrotation existed between the two types of tilt, with the greatest degree of counterrotation occurring with induced displacement; 2) no significant difference existed in neck or trunk lateral flexion; and 3) no significant differences existed in neck, trunk, or body anterior-posterior movement between tilts. We also found that a wide variability of response existed among the children over the three testing trials. Clinical application of our results suggests that different and unique motor programs exist for automatic and willed balance responses. These differences should be considered when planning treatment strategies.

**Key Words:** *Equilibrium, Movement, Physical therapy, Vestibular system.*

Treatment approaches aimed at the modification of motor dysfunction in the child with neurological impairment are based on theories of the development of motor control. The child's ability to maintain a stable, upright posture in the absence or presence of body or supporting surface displacement is considered a vital component in this developmental process. This ability, referred to as balance,<sup>1</sup> is dependent on head and trunk control.<sup>2-6</sup> To study the development of the components of motor control, consideration must be given to the planes within which the body moves. These planes are 1) the sagittal plane, in which flexion and extension against gravity occur; 2) the frontal plane, in which lateral flexion occurs; and 3) the transverse plane, which permits rotation

around the body's axis.<sup>7</sup> Flexion, extension, lateral flexion, rotation, and counterrotation occurring concurrently or in isolation comprise the movements responsible for head and trunk control.<sup>6</sup>

The child with motor dysfunction frequently lacks these elements of head and trunk control. When developing treatment strategies for these children, clinicians often attempt to recruit these movement patterns by eliciting automatic reactions. This recruitment is accomplished through the use of various displacement techniques, which include induced and self-induced lateral displacements.

Although these treatment approaches are used extensively, the rationale for their use is not based on scientific data. Baseline data regarding the kinematics of automatic balance reactions in healthy children are essential for the identification of movement dysfunction. Furthermore, such data would provide a scientific basis for the selection of treatment procedures.

Several studies have been conducted that document the ability or inability to maintain balance under various conditions. Martin, for example, investigated responses to various speeds of tilt while controlling for sensory mechanisms mediating the responses.<sup>8</sup> Stejskal observed

and documented movement patterns in response to displacement and concluded that the direction of trunk rotation was dependent on the degree of neck rotation.<sup>9</sup> Both of these investigators, however, studied adult subjects only. Stilwell and Heiniger, from their study of children's balance responses, concluded that as the angle of tilt during displacement increases, the child demonstrates an increase in trunk rotation and protective responses.<sup>10</sup> Although these and other investigations of balance reactions under various conditions are documented,<sup>8-19</sup> the lack of kinematic data, particularly of head and trunk responses, persists. Our study was designed to collect and compare kinematic data regarding head and trunk movement responses to induced versus self-induced lateral tilt in a tailor-sitting position.

## METHOD

### Subjects

Class rosters from two second-grade classrooms were used to obtain participants for the study. Subject selection criteria were 1) signed parental informed consent forms, 2) age between 7 years and 7 years 11 months, and 3) nor-

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malcy. For the purpose of this study, "normalcy" is used to describe any child who has not been diagnosed with, treated for, or recommended for treatment of neurological disorders, serious medical disorders, orthopedic deformities, high-risk infancy, prematurity (less than 37 weeks gestation), behavioral disorders, or learning disabilities. This information was obtained from a questionnaire completed by the subjects' parents. Of the 55 children surveyed, only 20 met all of the eligibility criteria. Our participants were 13 boys and 7 girls (including one set of twins) ranging in age from 7 years to 7 years 11 months, with a mean age of 7 years 3 months.

### Equipment and Procedure

Our study used a nonexperimental and nonrandomized design, with the participants serving as their own controls during the three displacement trials. The independent variables were 1) the two types of displacement (induced and self-induced tilt) and 2) the three trials for each subject. The dependent variables, recorded at three stages of tilt (original position, initiation of tilt, and full tilt), were neck lateral flexion, trunk lateral flexion, trunk counterrotation, anterior-posterior trunk movement, anterior-posterior neck movement, total anterior-posterior body movement, and the change in degree for each of these measures.

A 0.6- × 0.9- × 0.3-m rocker board was constructed, which for safety reasons allowed a maximum of 30 degrees of lateral tilt in either direction. Two strips of 5-cm masking tape were placed on the surface of the board such that its length was bisected and a consistent line was established 15.5 cm from its posterior aspect. To obtain slide transparencies for data collection, we used ASA 200 color film in a motor-driven, 35-mm camera that was mounted on a tripod and operated at a speed of 4 frames per second. Mirrors were placed at 45- and 90-degree angles to allow for clear and concurrent lateral and posterior views of each subject, thereby permitting simultaneous measurements of each dependent variable (Fig. 1). To ensure a consistent and accurate testing environment during each session, 2.5-cm masking tape was placed on the floor to mark the exact position and location of each piece of equipment. A plumb line was used as a consistent vertical reference point to allow for accurate, successive alignment of the slides during data collection.

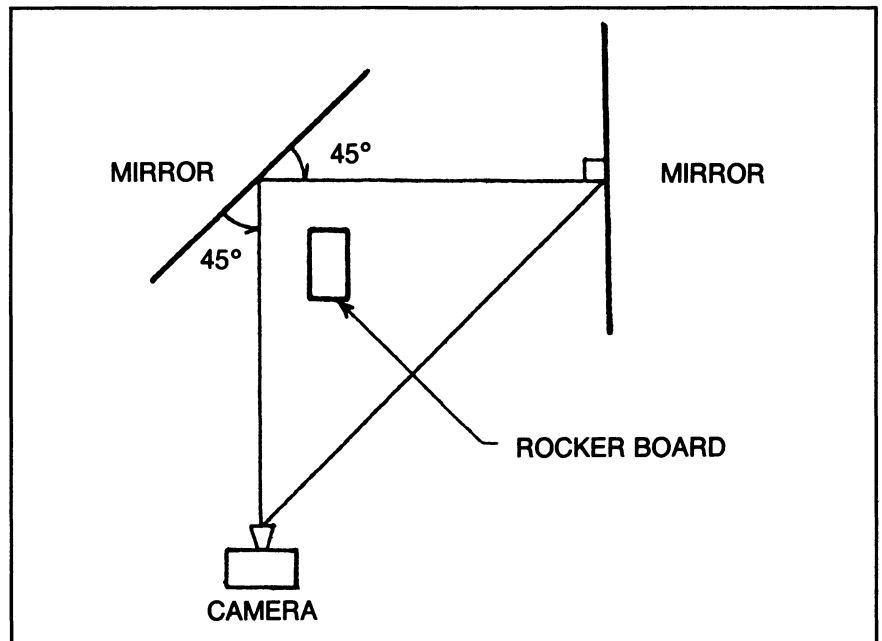


Fig. 1. Design of testing room.

Circular stickers, 2 cm in diameter, were placed on each subject on the following body landmarks: 1) medial aspects of the spines of the right and left scapulae, 2) medial posterior right and left iliac crests, 3) left acromion, and 4) left lateral iliac crest. A 12.3-cm diameter plastic ring was placed on the child's head and held in place by a chin strap. Three stickers were placed on the ring, one directly above the left ear lobule and two on the posterior aspect of the ring directly above the lateral aspects of the occiput. All of these markers permitted consistent alignment reference points to allow for accurate goniometric measurements.

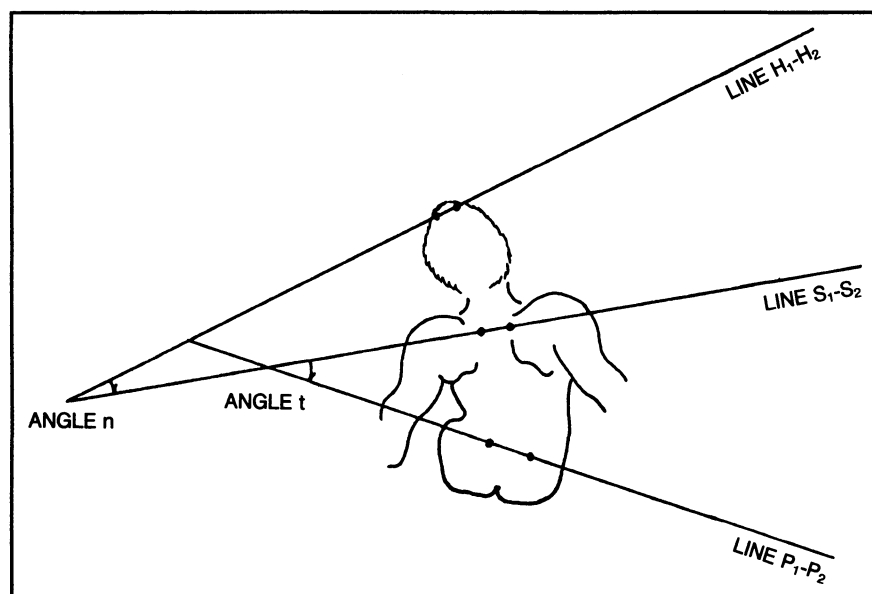
All children were placed in the tailor-sitting position on the rocker board at the intersection of the center and posterior strips of tape with their back toward the 90-degree mirror and their hands resting in their lap. For the induced tilt, we instructed the children to sit erect before tilting began and to attempt to maintain the sitting position throughout the entire tilting procedure (tilt to 30 degrees). No other instructions regarding how the child should or should not respond were given. The examiner said, "Ready, set, go," and began displacement to the left. This displacement was continued to a count of 1-2-3 (a period of about two seconds). The children also were displaced to the right; measurements were not recorded for right tilt, however, because the rocker board obscured the camera's view of the body landmarks when tilted to the right. For the self-induced tilt, the children

again were instructed to sit erect. On the examiner's command "ready, set, go," the subjects were instructed to tilt the board to the left until it touched the floor and to wait until the examiner returned them to the original position. They then were instructed to tip the board to the right. All children were able to tip the board through a full 30-degree tilt. For either tilt, when the board reached the floor, the examiner said, "Stop." Filming was commenced with the word "set" and was concluded with the word "stop." Each subject was allowed one practice trial of each tilt in each direction before testing. One examiner (D.M.) implemented the testing procedure for all subjects.

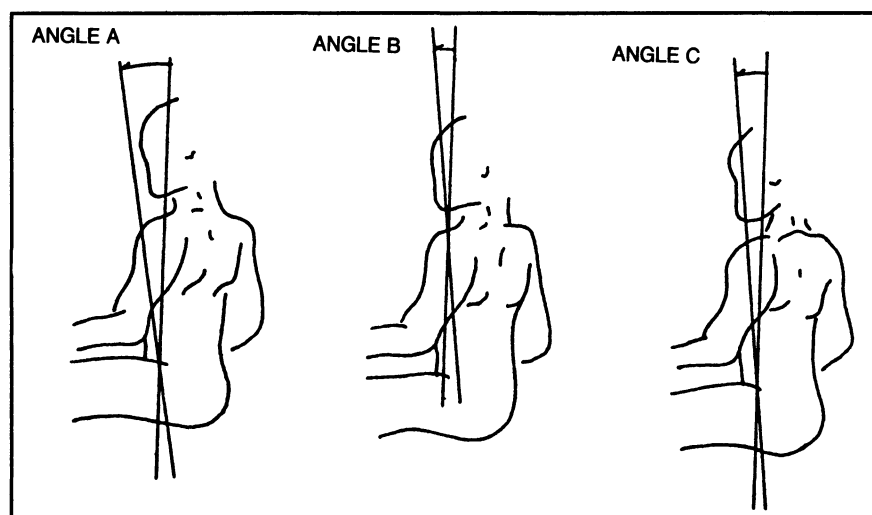
### Data Collection

Of the slides taken of each subject on each trial, the first, third, and last slides were used for data collection. The first slide was taken before any movement of the tiltboard began and, therefore, provided baseline data. The third slide coincided with the command "go," indicating the subject's initial response to the tilting procedure. The last slide corresponded to full tilt and, therefore, represented the maximum response to displacement. The slides were projected onto blank, white paper so that body landmarks could be transcribed to allow for goniometric measurements for each of these recording positions.

On the posterior view, horizontal lines were drawn parallel to the floor between the following landmarks: 1) the poste-



**Fig. 2.** Lateral flexion measurements. (Lines  $H_1-H_2$ ,  $S_1-S_2$ , and  $P_1-P_2$  represent horizontal lines through the posterior markers on the head ring, the scapulae, and the posterior iliac crests, respectively.)



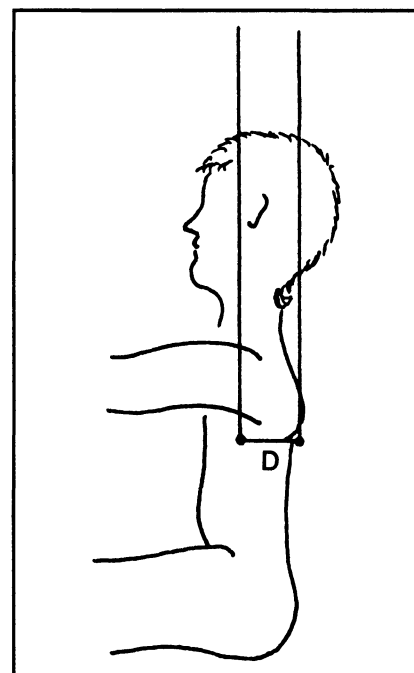
**Fig. 4.** Body angle measurements. (Angle A indicates anterior-posterior trunk movement; angle B indicates anterior-posterior neck movement; angle C indicates total anterior-posterior body movement.)

rior markers on the head ring, 2) the scapulae, and 3) the posterior iliac crests. Any changes in the orientation of these lines such that the line was no longer parallel indicated angular displacement. Neck lateral flexion was recorded as the angle (angle  $n$ ) that was created by changes in the orientation of the line through the head ring in relationship to the line through the scapulae. Trunk lateral flexion was recorded as the angle (angle  $t$ ) that was created by changes in the orientation of the line through the scapulae in relationship to the line through the iliac crests (Fig. 2).

On the lateral view, a horizontal line (linear distance  $D$ ) was drawn parallel to the floor and perpendicular to the midaxillary line and a vertical line

drawn through the last visible point of the posterior aspect of the body (Fig. 3). Based on the principles of rotational kinematics, any changes in this distance would indicate that rotation had occurred.<sup>20</sup> Furthermore, if the trunk rotated while the pelvis remained stable, as evidenced by the child's buttocks remaining on the posterior line on the rocker board, then trunk counterrotation had occurred. In our study, as  $D$  increased, the upper trunk rotated to the right with respect to the pelvis. Conversely, as  $D$  decreased, the upper trunk rotated to the left with respect to the pelvis.

Additional data were collected while viewing the lateral aspect of the child. Vertical lines were drawn parallel to the



**Fig. 3.** Lateral view of subject during counterrotation measurements. (Horizontal line  $D$  represents linear distance between midaxillary line and vertical line through the last visible point on the posterior aspect of the body.)

plumb line through the markers on the left lateral iliac crest, the left acromion, and the left lateral marker on the plastic ring. A line was drawn connecting the point of the iliac crest to the point on the acromion. The angle created between this line and the vertical line through the iliac crest (angle A) indicated anterior-posterior trunk movement. Another line was drawn connecting the acromion to the marker on the lateral aspect of the head ring. The angle created between this line and the vertical line through the acromion (angle B) indicated anterior-posterior neck movement. A third line was drawn connecting the lateral iliac crest to the lateral marker on the head ring. The angle created between this line and the vertical line through the iliac crest (angle C) indicated total anterior-posterior body movement (Fig. 4).

All angular measurements were recorded to the nearest five 10ths of a degree. Linear measurements were recorded to the nearest 10th of a centimeter. One examiner (D.M.) obtained all measurements.

### Data Analysis

The mean, range, and standard deviation for each of the dependent variables were determined (Tabs. 1, 2). A multivariate analysis of variance (MANOVA)

TABLE 1

Means and Standard Deviations of Dependent Variables for Induced Left Lateral Tilt

Condition <sup>a</sup>	Recording Position					
	Original Position (O)	Initial Tilt (I)	Difference from O to I	Full Tilt (F)	Difference from I to F	Difference from O to F
Angle A						
$\bar{X}$	16.21	17.43	1.21	19.95	2.52	5.74
s	3.75	5.62	4.68	6.80	6.11	5.77
Angle B						
$\bar{X}$	11.38	10.98	-0.38	8.64	-1.47	-1.81
s	8.68	11.57	8.26	14.79	7.37	12.80
Angle C						
$\bar{X}$	13.81	14.05	0.24	15.76	1.71	1.95
s	5.21	5.89	3.67	6.06	4.48	5.80
Distance D <sup>b</sup>						
$\bar{X}$	1.65	1.89	0.24	2.25	0.36	0.59
s	0.35	0.36	0.41	0.62	0.47	0.61
Angle t						
$\bar{X}$	0.02	24.07	24.05	33.10	10.93	34.40
s	2.22	12.44	11.99	18.75	14.31	16.83
Angle n						
$\bar{X}$	0.62	5.93	5.31	12.04	12.88	13.67
s	2.36	22.79	22.92	22.87	24.71	24.36

<sup>a</sup> Angles measured in degrees; distance measured in centimeters.

<sup>b</sup> For distance D, increases indicate rotation to the right; decreases indicate rotation to the left.

was used to test the significance of mean differences between the degree of head and trunk responses at the three recording positions and 1) source of tilt, 2) trial, and 3) interaction effects of source of tilt with trial. A level of significance was established a priori at .05.

Another registered physical therapist, not involved with this study, was asked to select randomly the slides of 10 subjects and transcribe the body landmarks as described previously. The examiner used these transcription points to take measurements of the dependent variables. The measurements collected from the second recorder's transcriptions were correlated with those collected from the examiner's transcriptions to establish interrater reliability. The second recorder also was asked to select randomly the slides of 10 subjects whose transcriptions were completed by the examiner and to collect measurements of the dependent variables. The measurements collected by the second recorder and the examiner then were correlated to establish interrater reliability. Interrater reliability for body landmark transcription and measurements of dependent variables after transcription was established using a Pearson product-moment correlation analysis.

## RESULTS

Based on our data analysis, we found that the types of movements or compo-

nents of response were the same for each subject during each form of tilt. Each subject demonstrated lateral flexion and counterrotation. Quantitatively, however, the measures of response are different.

The mean scores and standard deviations for the change in linear distance D from initial tilt to full tilt and from original position to full tilt, with source of displacement as a factor, was significant (Tab. 3). For both of these trunk counterrotation measures, the greatest change occurred with the induced rather than the self-induced lateral tilt.

No significant differences were found among the other dependent variables with source of displacement as a factor. Use of the MANOVA also allows for analysis of the interaction effects between the dependent and the independent variables. We found no significant differences attributable to these interaction effects.

Review of Tables 1 and 2 reveals a large standard deviation for each variable. The MANOVA, however, indicated that each subject's response was consistent for each trial. Individual consistency accompanied by group disparity indicates that although each subject was consistent over the three trials, a large variation of response existed between subjects.

The results of the interrater reliability analysis for transcription of body landmarks were greater than .85 for all de-

pendent variables. Interrater reliability analysis for the measurement procedures revealed coefficients greater than .99 for all dependent variables.

## DISCUSSION

Both automatic and learned automatic movements rely on the execution of preprogrammed movement responses, which more accurately are referred to as *motor programs*.<sup>21</sup> Marsden described a motor program as a pre-established set of motor commands that will produce a motor response in the absence of peripheral feedback.<sup>21</sup> For the central nervous system to recruit and execute an appropriate motor program, it must be informed of the desired motor outcome. This function is called the *motor plan*. A motor plan, therefore, is responsible for the selection of a motor program based on the desired response.

Brooks referred to unmodulated, preprogrammed responses as *ballistic movements*.<sup>22</sup> Although these programs may be executed without peripheral feedback, such feedback is used to monitor and to alter the movement responses so that the original motor plan can be realized. This feedback consists of peripheral sensory information regarding the environment, in addition to internal mechanisms monitoring the program in process.<sup>22</sup>

The results of our study indicate that differences exist in the body's response

**TABLE 2**  
Means and Standard Deviations of Dependent Variables for Self-Induced Lateral Tilt

Condition <sup>a</sup>	Recording Position					
	Original Position (O)	Initial Tilt (I)	Difference from O to I	Full Tilt (F)	Difference from I to F	Difference from O to F
Angle A						
$\bar{X}$	17.11	18.40	1.29	19.67	1.26	2.93
s	18.22	8.38	4.97	8.26	6.21	8.55
Angle B						
$\bar{X}$	12.02	14.74	3.52	16.43	2.31	4.40
s	10.62	13.30	10.17	13.42	13.15	12.63
Angle C						
$\bar{X}$	14.74	16.93	2.91	17.14	0.21	2.36
s	7.14	8.31	3.90	8.31	5.41	6.75
Distance D <sup>b</sup>						
$\bar{X}$	1.65	1.81	0.16	1.92	0.10	0.26
s	0.38	0.43	0.24	0.54	0.22	0.34
Angle t						
$\bar{X}$	-0.88	20.33	19.14	37.88	17.55	38.76
s	3.38	20.57	24.14	18.24	28.27	18.16
Angle n						
$\bar{X}$	1.07	13.71	12.86	19.07	15.45	18.21
s	2.05	29.17	29.46	35.68	36.68	36.23

<sup>a</sup> Angles measured in degrees; distance measured in centimeters.

<sup>b</sup> For distance D, increases indicate rotation to the right; decreases indicate rotation to the left.

to induced and self-induced lateral tilt. One explanation for this finding is that the movement responses, via the motor program, are mediated at two different levels of motor activity. The movement response that results from the induced tilt is initiated by an external stimulus, whereas the self-induced tilt is initiated internally. The difference in response may arise because the induced tilt requires execution of an automatic motor program, whereas the self-induced tilt requires execution of a learned automatic, or skilled, motor program.

Although our data analysis revealed a significant difference in the degree of trunk counterrotation, it showed no significant difference in movement components with source of tilt as a factor. Lack of significant differences in the movement components would imply that for both induced and self-induced tilt the motor plans were identical to maintain a stable posture. Although the motor plans were identical, the significant differences in the degree of trunk counterrotation would indicate that different motor programs were used in the execution of the motor plan.

Furthermore, although significant differences in response were found that were due to the source of displacement, no significant differences in response were found over the three testing trials. The consistency of these responses over each trial implies that the motor pro-

**TABLE 3**  
Multivariate Analysis of Variance Results with Source of Displacement as a Factor

Dependent Variable	df	SS	F	p
Distance D				
Full tilt-initial position	40	0.67	4.90	.03
Distance D				
Full tilt-original position	40	1.13	4.62	.04

grams used during each trial for each of the tasks were identical.

The large standard deviations calculated for the dependent variables suggest that a wide variability of balance responses existed in the children. This variability of response implies that the motor programs for automatic and learned automatic activities are unique to each child. This variability may be attributable to 1) maturation of the child's ability to maintain sitting, 2) size of the child, and 3) individual balance abilities and past experiences. Studies by Cook<sup>12</sup> and Shambes<sup>23</sup> indicate that by the age of 7 years, the ability to balance (both statically and dynamically) is mature. The possible lack of mature responses in the children tested, therefore, should not contribute to the variability of response. The size of the child could affect the actual measurements in degrees or centimeters, but would not affect the proportional change from one condition to the next. The children could, and most assuredly did, vary in their past experiences and balance abilities. This

factor, therefore, could explain the variability of response from one child to the next. Further studies will be needed to determine the appropriate range of responses for specific ages and body sizes.

### Clinical Implications

Possible clinical implications of these data must be considered in the selection of treatment strategies and in the identification of deficits in balance abilities. Based on the premise of the existence of diverse motor programs for both automatic and learned automatic motor activities, we suggest that clinicians attempt to identify the level of motor activity that is affected or lacking in their clients (eg, automatic vs willed). After this level of motor activity is identified, treatment should commence with activities aimed at facilitating the components of that level. On the basis of our study, we can neither support nor reject the concept of therapists using existing motor programs for one level of motor activity in an attempt to establish motor

programs for a different level of motor activity.

Therapists also must consider the uniqueness of each motor program for each child. Based on this uniqueness of response, evaluating the child's ability or inability to maintain a posture may be more appropriate than identifying "normal" reactions according to the degree and direction of the response. Until the range of normal reactions has been identified, only gross assessments can be made regarding the presence of balance abilities. Ultimately, the variety in proximal response to displacement indicates that for head and trunk control to be established, a child must develop various interactive movement patterns.

The ability to modify motor programs is affected by peripheral feedback mechanisms. This factor must be considered in the identification of deficits and in the selection of treatment strategies to facilitate the alleviation of those deficits. Clients with developmental disabilities or neurological deficits also usually demonstrate perceptual or sensory deficits. When selecting treatment procedures, therefore, therapists should consider the interaction effects of sensory, perceptual, and motor systems.

Another clinical implication that must be considered when evaluating these data is that a greater degree of trunk counterrotation occurs with induced versus self-induced lateral tilt. Those therapists who attempt to facilitate trunk counterrotation for the pur-

poses of relaxation or mobilization should consider using induced rather than self-induced tilt to achieve a maximal response. We cannot conclude from these data that induced lateral tilt will improve trunk counterrotation for all levels of motor activity.

### Future Studies

Although our study was a preliminary investigation to identify the proximal components contributing to balance control, it did not identify the specific sequence of motor recruitment nor the mechanisms involved in the acquisition of postural control. This information could help to determine whether the variability of response is due to different motor programs or to the degree of muscle activation. Uniqueness of response is established, but further studies are necessary to determine whether variability 1) is evident at the commencement of skill acquisition or appears later, 2) changes as the child acquires the skill, or 3) is essentially a style developed as a result of an individual's experience superimposed on the basic skill. Additional studies also must address the changes in response occurring with various levels of perceptual development.

### CONCLUSION

In our study, we investigated 20 healthy 7-year-old children's head and

trunk movement responses to induced versus self-induced lateral tilt. Based on the data collected and analyzed, we found that a significant difference in trunk counterrotation existed between the two sources of displacement, with induced lateral tilt producing a greater response than self-induced tilt. We also found no significant differences in neck or trunk lateral flexion with either induced or self-induced lateral tilt. One interesting finding in our study was the wide variability of head and trunk responses between subjects. Moreover, although a wide range of response existed among the children, each child's response was consistent over the three testing trials.

Further study of the normalcy of response and of strategies affecting responses in children both with and without identified balance deficits is needed to further our understanding of the acquisition of motor control. The efficacy of therapeutic intervention strategies then can be investigated.

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